

ALLOWED CLAIMS

1. A method of electroplanarizing a metal layer disposed on a wafer work surface, said metal layer having a plurality of recessed regions and a plurality of raised regions on the field, the method comprising:
 - (a) selectively forming a diffusion barrier film on the metal layer;
 - (b) immersing a wafer holder into an electrolyte solution containing an electropolishing pad;
 - (c) creating relative movement between the metal layer and the electropolishing pad;
 - (d) bringing the wafer work surface and the electropolishing pad into proximity or contact with each other;
 - (e) passing an anodic electrical current from the wafer through the electrolyte solution and to a cathode to selectively remove regions of the metal layer exposed through the diffusion barrier film; and
 - (f) stopping the passage of current at a point where all or a majority of the metal layer is removed from the field.
2. The method of claim 1, wherein a wafer holder, which holds the wafer, is configured to supply the anodic electrical current to the metal layer.
4. The method of claim 1, wherein selectively applying a diffusion barrier film to the metal layer comprises at least one of dipping, spraying, and metering.
5. The method of claim 1, further comprising removing a portion of the diffusion barrier film from the plurality of raised regions on the field via mechanical polishing, wherein the diffusion barrier film is a solid.
6. The method of claim 2, wherein (c) comprises rotating the wafer, via the wafer holder, about an axis perpendicular to its work surface, while the electropolishing pad remains motionless about the same axis.
7. The method of claim 1, wherein (d) comprises bringing the wafer work surface and the electropolishing pad into contact with each other.
8. The method of claim 7, wherein the electropolishing pad is abrasive.

9. The method of claim 7, wherein the electropolishing pad is non-abrasive.
10. The method of claim 1, wherein the electropolishing pad has pores of between about 0.02 μ m and 10 μ m in diameter.
11. The method of claim 1, wherein the electrolyte traverses a flow manifold before flowing through the electropolishing pad and onto the wafer work surface.
12. The method of claim 11, wherein the flow manifold, in conjunction with the electropolishing pad, creates a uniform laminar flow front in the electrolyte, which impinges upon the wafer work surface.
13. The method of claim 11, wherein the electrolyte flows through a diffuser membrane before entering the flow manifold.
14. The method of claim 1, wherein the electrolyte contains coppers ions.
15. The method of claim 1, wherein the electrolyte is an acidic medium.
16. The method of claim 15, wherein the electrolyte contains between about 30 and 80 weight percent phosphoric acid.
17. The method of claim 16, wherein the electrolyte contains between about 0.1M and near saturated copper phosphate.
18. The method of claim 1, wherein the electrolyte is a basic medium.
19. The method of claim 18, wherein the electrolyte contains a complexing agent.
20. The method of claim 18, wherein the electrolyte contains tetraalkylammonium ions.
21. The method of claim 1, wherein the electropolishing pad has a void volume of between about 20 and 80 percent.

22. The method of claim 1, wherein the diffusion barrier film is a viscous liquid which is soluble in the electrolyte.
23. The method of claim 22, wherein the viscous liquid comprises at least about 40 weight percent phosphoric acid.
24. The method of claim 22, wherein the viscous liquid comprises between about 70 and 100 weight percent phosphoric acid.
25. The method of claim 23, wherein the viscous liquid further comprises at least one of water, propylene carbonate, ethylene carbonate, and sulfuric acid.
26. The method of claim 22, wherein the viscous liquid comprises a metal salt.
27. The method of claim 1, wherein the diffusion barrier film is a solid which is insoluble in the electrolyte.
28. The method of claim 27, wherein the solid is non-conductive to ions generated during electropolishing the metal layer.
29. The method of claim 1, wherein the diffusion barrier film comprises a polymer.
30. The method of claim 29, wherein the polymer is polyvinylidene difluoride or EPDM.
31. The method of claim 22, wherein the viscous liquid comprises at least one of concentrated phosphoric acid, concentrated sulfuric acid, boric acid, glacial acetic acid, ethylene glycol, propylene glycol, poly-oxy-ethylene glycols of molecular weights varying from 100 to 20,000, poly-oxy-propylene glycols of molecular weights varying from 100 to 20,000, and mixtures thereof.
32. The method of claim 26, wherein the metal salt comprises at least one of copper sulfate (CuSO_4), copper phosphate ($\text{Cu}_3(\text{PO}_4)_2$), cupric monohydrogen phosphate (CuHPO_4), copper monohydroxy phosphate ($\text{Cu}_2(\text{OH})\text{PO}_4$), and copper nitrate ($\text{Cu}(\text{NO}_3)_2$).

33. The method of claim 26, wherein the metal salt is formed by reaction of an acid in the diffusion barrier film or the electrolyte with at least one of Cu₂O, CuO, and Cu(OH)₂.
34. The method of claim 22, wherein the viscous liquid comprises at least one of a brightening agent, a wetting agent, a material that promotes uniform electropolishing, and a kinetically inhibiting agent.
35. The method of claim 34, wherein the brightening agent comprises at least one of coumarin, benzotriazole, MPS (mercaptopropane sulphonic acid) and SPS (di-mercaptopropane sulphonic acid).
36. The method of claim 34, wherein the wetting agent comprises at least one of sodium lauryl sulfate, co-polymers of poly-oxy-ethylene glycol (PEG), and co-polymers of poly-oxy-propylene glycol (PPG).
37. The method of claim 34, wherein the material that promotes uniform electropolishing comprises at least one of polyethylene glycol, polyethylene oxide, polypropylene oxide, polypropylene glycol, and copolymers thereof.
38. The method of claim 34, wherein the kinetically inhibiting agent comprises at least one of 4-methylimidiazole, 1-phenyl-4-methyl imidazole, and 1-(p-tolyl)-4-methylimidiazole.
39. The method of claim 34, wherein the viscous liquid further comprises between about 10 and 100 ppm of chloride ion.
40. The method of claim 34, wherein the viscous liquid further comprises between about 0 and 1 mole/liter of an electrochemically stable salt to reduce potential drop of the electroplating process and to enhance polishing performance.
41. The method of claim 40, where the electrochemically stable salt comprises at least one of tetraethylammonium tetrafluoroborate and dodecyl trimethyl ammonium tetrafluoroborate.
42. The method of claim 32, wherein the concentration of the metal salt in the film is at least about 0.1 mole/liter.

43. The method of claim 32, wherein the concentration of the metal salt is at least about 0.25 mole/liter.
44. The method of claim 32, wherein the concentration of the metal salt is at least about 0.5 mole/liter.
45. The method of claim 1, wherein (e) occurs prior to (d).
46. The method of claim 1, further comprising adjusting the relative position of the electropolishing pad and the wafer so as to maintain electropolishing, after (e) and before (f).
47. A method of electrochemically planarizing a metal layer deposited on a wafer, the method comprising:
 - (a) applying a diffusion barrier film to a metal layer on the surface of a wafer;
 - (b) removing the diffusion barrier film to expose only areas of highest elevation of the metal layer; and
 - (c) electrochemically removing metal from the exposed regions of the metal layer until a newly defined field region is reached;
wherein (b) and (c) are repeated iteratively until a predetermined degree of planarization of the metal layer is achieved.
48. The method of claim 47, wherein (b) is achieved via mechanical removal with a polishing pad.
49. The method of claim 48, wherein the diffusion barrier film is a viscous liquid that is soluble in an electrolyte used in (c).
50. The method of claim 49, wherein the viscous liquid comprises at least about 40 weight percent phosphoric acid.
51. The method of claim 49, wherein the viscous liquid comprises between about 70 and 100 weight percent phosphoric acid.
52. The method of claim 49, wherein the viscous liquid comprises at least one of water, propylene carbonate, ethylene carbonate, and sulfuric acid.

53. The method of claim 49, wherein the viscous liquid comprises a metal salt.
54. The method of claim 49, wherein the viscous liquid comprises at least one of concentrated phosphoric acid, concentrated sulfuric acid, boric acid, glacial acetic acid, ethylene glycol, propylene glycol, poly-oxy-ethylene glycols of molecular weights varying from 100 to 20,000, poly-oxy-propylene glycols of molecular weights varying from 100 to 20,000, and mixtures thereof.
55. The method of claim 47, wherein the diffusion barrier film is a solid that is insoluble in an electrolyte used in (c).
56. The method of claim 55, wherein (b) is achieved via dissolving the uppermost portion of the diffusion barrier film with a solvent.
57. The method of claim 55, wherein the solid is non-conductive to ions generated during (c).
58. The method of claim 56, wherein the solid comprises a polymer.
59. The method of claim 58, wherein the polymer is polyvinylidene difluoride and the solvent is at least one of DMF and NMP.
60. The method of claim 58, wherein the polymer is ethylene propylene diene monomer and the solvent is cyclohexane.